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THE BI-POLAR CELLS OF THE SPINAL CORD AND THEIR CONNECTIONS.

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Examination of the spinal cord of man in reference to the connections of the cells of Clarke's column, the intermedio-lateral, and the solitary cells of the posterior horn, is attended with many difficulties, which the anterior cornual cells do not offer. The latter, multipolar cells, give origin to the large fibres of the anterior roots, and are connected with similar cells above and below, and in the opposite anterior cornu. It would seem probable that their multipolar character is associated with these connections. The other cells of the cord are, for the most part, simply bi-polar. There is good reason to believe that nerve fibres bear a relation in size to the cells in which they originate. It is also probable that a nerve cell is larger when the nerve formed by its axis-cylinder process has a long course before it comes to its final termination. Hence the anterior cornual cells of the lumbar or cervical enlargements are larger than are met with elsewhere. A fibre, however, may branch after leaving the cell, as happens in the T-shaped fibre of the cells of the ganglion on the posterior root (Ranvier). This, however, does not apply to the fibres met with in the anterior roots, and it may be concluded that Gaskell[1] is right in regarding small fibres as originating from small cells. He has shown that in the anterior roots throughout the dorsal region are numerous *fine medullated fibres* (leucenteric). These also are found in the second sacral root, and in the upper cervical region, and form the viscero-vascular rami communicantes. If his first statement be accepted, that small fibres arise from small cells, the second statement that they originate from Clarke's column, which undoubtedly agrees in its distribution with this outflow of fine fibres by the anterior roots, cannot be accepted, because the cells of Clarke's vesicular column are by no means small, measuring where the column is well developed, 90 μ, and even the smallest cells (40 μ) are larger than the cells of two other groups, which he admitted might possibly be the source of fine fibres, and which I shall endeavour to show is much more probable. In fact, although text books state that Gaskell[1] has proved that these fine efferent fibres originate in Clarke's column, the whole evidence to support this hypothesis rests upon the assumption that because the cells of this posterior vesicular column are so placed in the cord as to agree in situation with the outflow of these fibres, therefore they give origin to them. No microscopical evidence tends to support this view. Occasionally fibres may be seen running from Clarke's column to the anterior cornua; especially have I noticed this in the mid-dorsal region. But the fibres cannot be traced into the anterior roots, and it may be that some of them pass into the anterior commissure as Bechterew states. Even this does not show that the fibres have originated from the cells of Clarke's column—in fact, they may be merely fibres passing out of the postero-external column on their way to the anterior horns.

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[1] 'Journal of Physiology,' vol. vii.

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[1] Dr. Gaskell sums up his views of the functions of the various groups of the spinal cord:—(*a*) Cells of anterior horn = nucleus of efferent nerves to somatic muscles. (*b*) Large cells of lateral horn = nucleus of efferent nerves to striated splanchnic muscles. (*c*) Cells of Clarke's column = nucleus of anabolic (inhibitory) nerves to splanchnic glandular system and to muscles of viscera and vascular system. (*d*) Solitary cells of posterior horn = nucleus of motor nerves to muscles of viscera. (*e*) Small cells of lateral horn = nucleus of katabolic (motor) nerves to splanchnic glandular system and to muscles of vascular system.—"On the Relation between the Structure, Function, Distribution and Origin of the Cranial Nerves; together with a Theory of the Origin of the Nervous System of Vertebrata." By W. H. Gaskell, M.D., F.R.S. 'Journal of Physiology,' vol. x.

Microscopical examination, however, shows beyond a doubt that fibres of the postero-external column, coming from the sacral and lumbar nerves, have their station in the lower part of Clarke's column. Physiological experiments in monkeys and pathological investigations in cases of injury and diseases of the roots of the cauda equina show degeneration of the fine nerve plexus around the cells of the posterior vesicular column.

The evidence of the lower connection of this group of cells will be first considered microscopically. If the cord of a fœtus be examined in the lower dorsal region, sections stained by Weigert's method show bundles of fibres passing out of the postero-external column into the posterior horn like a brush (*vide* micro-photograph 1.), and limiting on the outside a group of cells lying in neuroglia substance. The cells are not larger than the adjacent solitary cells, and there is very little evidence of any fine plexus of nerve fibrillæ around them. The cells measure at this period about 20 μ (average).

At successive periods of growth of the spinal cord, namely, four months, nine months, two years, and adult, transverse vertical sections showed the cells to be slowly increasing in size. At two years they are three times as large, 60 μ, and in the adult even more than that, measuring on an average 70 μ (*vide* micro-photograph 2). The latter measurement agrees pretty accurately with the average size determined by Sherrington.[1]

In the spinal cord of a child two years old I was fortunate enough to obtain a section showing fibres passing out of the postero-external column, breaking up into a fine brush of fibrillæ, with varicosities thereon around the cells of the column. (See fig. 2.)

Examinations of other sections from a very well-hardened adult spinal cord, made in a vertical direction, showed the cells placed with their long axis vertical, lying in lymph spaces, surrounded by a spongy network of fine nerve fibrillæ. These could be traced across the lymph space into actual protoplasmic continuity with the cell. (See micro-photograph 3.)

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[1] Philosophical Trans. R. Society, vol. clxxxi., p. 33-48; 'Outlying Nerve Cells in the Mammalian Spinal Cord,' by C. S. Sherrington, M.A., M.B.

It is possible that the cells stain a sepia colour by Weigert's[1] method, on account of the cell being covered with these delicate fibrils, the optical section of which give it its fine granular appearance. This fine plexus has long been known to be atrophied in cases of tabes dorsalis, and in injury of the roots of the cauda equina, associated with a sclerosis of the fibres of the postero-external column. The striking features of tabes which may be associated with this pathological change, are absence of the knee jerks, and loss of the guiding sensations, which normally operate in a reflex manner in the production of unconscious equilibration. Visceral disturbances are not at all uncommon, and Dr. Ross was the first to suggest that visceral crises and other disturbances were due to affection of the cells of Clarke's column.

It is possible, as suggested by Dr. Ferrier,[2] that along with tactile, common sensory, visual or labyrinthine impressions, other sensory impressions are correlated in the cerebellum, with the motor adjustments necessary for stability and equilibration. It may be that visceral or organic sensory impressions are represented in the cerebellum, but it is quite probable that other smaller cells in the immediate neighbourhood of Clarke's column, namely, the solitary cells, or the cells of the intermedio-lateral tract convey these organic sensations. Lissauer and Krauss, Oppenheim and Sœmmerling,[3] and others, have shown that the earliest change in locomotor ataxy is an atrophy of this fine nerve plexus. I described a case of injury to the roots of the cauda equina which showed this condition, together with a sclerosis of the fibres entering it from the postero-external column.[1] The cells were somewhat shrunken, but there was no degeneration in the direct cerebellar tract. Cases of tabes have been mentioned to me in which the cells of Clarke's column were absent, but there was no degeneration in the cerebellar tract. This was due, as afterwards found at my suggestion, to the cells having tumbled out owing to the atrophy of the supporting fine plexus. For when the same cord was examined, after imbedding in celloidin, the cells were found to be as numerous as in normal sections.

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[1] Ct. Lenbossek, *Archiv. Microsk. Annat*, v. xxxiii., 1889.

[2] *Functions of the Brain.*

[3] Krauss, *Zur Pathol. Anat. der Tabes Dorsalis*, *Neurol. Centralblatt*, Feb. 1st, 1885; Lissauer, *Archiv. fur Psychiatrie u. Nervenkrankheiten*, 1885; Oppenheim and Sœmmerling, *Archiv. fur Psychiatrie* vol. xx.

With a view of determining the connection of the cells of Clarke's column with the fibres of the posterior roots, I made the following experiments :[2]—Unilateral section of the posterior roots of the cauda equina was made in two monkeys, the lower lumbar and sacral nerves being divided. The animals lost sensation in the lower limb of the same side, and there was absence of the knee-jerk. They were killed at the end of a month with chloroform. On microscopical examination of sections stained by Weigert's method the following degenerations are observed :—In the lower lumbar and upper sacral segments corresponding to the roots divided, there is complete degeneration of all the fibres entering the posterior horn, and a uni-lateral degeneration of the whole posterior column, except a small triangular area at the outer extremity of the posterior median fissure. Neither internal, central, nor external root fibres are seen, and there is a complete absence of the border zone of Lissauer. Moreover, an ascending bundle of small fibres seen at the outer part of the posterior horn of the uninjured side is quite absent. At the junction of the first and second lumbar segments the root fibres are seen undegenerated, and a triangular wedge of undegenerated fibres makes its appearance to the median side of the posterior horn. An examination of Clarke's column at this level shows an absence of the fibres which

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[1] 'Journal of Anat. and Physiology,' vol. xxii., "On the Microscopical Examination of Clarke's Column in Man, the Monkey, and the Dog."

[2] These experiments were performed at the Brown Institution in the year 1888, by the kind permission of Professor Horsley.

pass from the postero-external column, and on the side of the lesion atrophy of the fine fibrillary plexus in which these fibres terminate. The number of cells is about equal on the two sides, but the difference in appearance of the fine fibrillary plexus was most marked in every section, notwithstanding the great number examined. The fibres which enter Clarke's column from the postero-external column may be divided into two sets, those which come from the outer division of the inner root fibres, and those which seem rather to limit Clarke's column than enter into the formation of the fine fibrillary network. Just above the lesion these fibres which run on the outside of the column, begin to appear, but still the fine nerve network around the cells is atrophied for some considerable distance above the lesion. In fact, it is not until we come to the seventh dorsal segment, where Clarke's column has become comparatively small, that the fine fibrillary plexus appears equal on the two sides. Coincident with this is an absence of all degeneration except in Goll's column; that is to say, not until the degenerated fibres have all disappeared from the postero-external column, does Clarke's column, as regards its fine plexus of fibrillæ appear the same on the two sides. The degeneration of Goll's column can be traced up to the post-pyramidal nucleus. The area of degeneration is smaller the higher it exists in the cord—probably due to the fibres themselves becoming smaller.

The degenerations are indicated in figs. 1 and 5. It seems probable to me that most of these large fibres which end in Clarke's column, and which degenerate when the lower roots of the cauda equina are divided, are supplied by the nerves of the lower extremity. These results accord with those of Tooth, with regard to the area of degeneration resulting from unilateral section of the roots of the cauda equina.[1]

Lissauer and Krauss, from their observations on the degeneration of the spinal cord in tabes, conclude that those fibres which lie most internally are most degenerated; and it is remarkable that the fibres which are most degenerated come from the lower roots, while those which form the outer group come from roots higher up.

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[1] "Degenerations of the Spinal Cord," Gulstonian Lectures, 1890, Howard Tooth.

Sherrington,[1] in an exhaustive account of the outlying nerve cells of the mammalian spinal cord, makes the following statement :—

"That the cells of Clarke's column are connected on their proximal side with the fibres of the cerebellar tract admits of little doubt; as to their distal connections it may be said that two views are current. The one which has been supported by Mott is that the cells are connected with afferent fibres—fibres of the posterior root. The other (Gaskell, Hill) is that Clarke's column is connected with the efferent fibres of anterior roots. Of these views the former, I think, derives support from the facts observed with regard to outlying cells in the posterior root zone of the cord. But it is difficult to believe that these outlying cells, although they appear equivalent to members of Clarke's column, can be at all closely connected with any fibres in the anterior root. Indeed it appears more likely that not only the vesicular group of Clarke, and the outlying cells of the external posterior column, but also the cells appearing in or near the gelatinosa, all belong to the afferent system entering by the posterior root."

Histology, physiological experiment and pathological observations all tend to prove that the cells of Clarke's column are brought into relation with fibres of the postero-external column by means of the fine nerve network in which these fibres end.

We have now to consider the upper connection of Clarke's column. As already stated, histological observations tend to show that the cells of Clarke's column give off large fibres, which run upwards, slightly forward, and then outwards through the lateral column, to reach the direct cerebellar tract of the same side. Pathological observations strongly support this view, although Tooth[1] places the point of origin of the fibres in the direct cerebellar tract as somewhere between the ninth and eleventh dorsal, and states that it is probably higher in the monkey. He also concludes that the posterior vesicular column is in connection with fine fibres, because compression of the cord below the ninth dorsal (where the column is best developed) has, in a number of instances, not produced any degeneration in the direct cerebellar tract. He argues, therefore, that these cells cannot be the source of the fibres of this tract, but rather are connected with fine fibres which may ascend in the posterior median and antero-lateral. With regard to the former conclusion, neither pathology nor experiment supports it. I have lately recorded a case in which there is complete degeneration of the whole of Goll's column, with no degeneration elsewhere in the cord, Clarke's column being perfectly normal. Neither does his conclusion agree with the results of unilateral section of the posterior roots.[1]

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[1] *Loc. cit.*

Finally, Dr. Tooth (page 60) states that the "*true* direct cerebellar tract consists of large fibres, the antero-lateral principally of small ones. The direct cerebellar tract derives its fibres from the posterior roots, the antero-lateral from the grey matter of the cord—at any rate not from the posterior roots." I must confess that I cannot understand, if this be so, why no degeneration of the direct cerebellar tract results from section of the posterior roots of the cauda equina. The reason why degeneration of the direct cerebellar tract does not occur unless the compression is at the ninth dorsal or above it may probably be accounted for in this way:—the tract itself does not exist as a collection of fibres on the periphery of the cord until we reach the ninth dorsal, because the fibres which form it have to pass upwards, forwards, and outwards through the lateral column. A transverse section[2] of Clarke's column shows numbers of large fibres cut transversely. Moreover, the cells are placed, except in the lowest part, with the long axis vertical. These large fibres I believe to be the medullated axis cylinder processes of the large bi-polar cells. The very position of the posterior vesicular column in the centre of the cord would necessitate a severe crush in order to destroy the cells and their fibres. Whereas a much slighter compression, for example by a tumour,

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[1] *International Journal of Medical Science*, January, 1891.

[2] *Vide* micro-photograph 2.

higher up, where these fibres have come to the surface, would more readily injure them. The evidence which supports the view that the cells of Clarke's column give off fibres which are continued upwards as the direct cerebellar tract is supported by the study of the development of this tract in the fœtal spinal cord by Flechsig, Bechterew, and others. I have myself observed in the fœtal spinal cord, passing out across the base of the posterior cornu, numbers of fibres which can be traced outwards through the front of the still unformed pyramidal tract. Vertical and transverse sections of the spinal cord in the lower dorsal region show large fibres passing out from the large bi-polar cells of this column, but they cannot be traced throughout the whole extent of their course, because they run upwards, forwards and outwards, and therefore, whether the sections be made transverse or vertical, their continuity must be severed. The fibres cannot, therefore, be traced directly from the cell into the direct cerebellar tract. With the appearance of the cells of Clarke's column in the lower dorsal region I have noticed large fibres scattered through the lateral column. To make more certain of this connection I made the following experiment. Unilateral section of the posterior-vesicular column was effected in a monkey at the level of the twelfth dorsal and first lumbar segments, and the animal was killed with chloroform after twenty days. A microscopical examination of the cord after hardening in bichromate of ammonia and staining by Weigert's method showed that the posterior column on the side of the lesion was almost completely destroyed; at the same time there was destruction of the grey matter on that side. (See micro-photograph 4.)

Microscopical examination of the sections with a high power showed, on the same side as the lesion, a complete atrophy of Clarke's column and disappearance of the nerve cells and fibrillary plexus at the level of the twelfth dorsal and first lumbar segments (*vide* micro-photo 5). At the ninth and tenth dorsal degenerated fibres were seen coursing out through the lateral column, and above this they were seen to reach the periphery; at the sixth dorsal the whole of the degenerated fibres *had* reached the position of the direct cerebellar tract (*vide* micro-photo 6), and there were now no degenerated fibres seen in the cross pyramidal, thus coinciding with the experiment of Dr. Sherrington[1] upon descending degenerations. He found that a number of large fibres in the cross pyramidal tract of the lower dorsal region did not undergo degeneration; in all probability they were these fibres. Another fact which supports Dr. Sherrington's views is that the degenerated fibres in the direct cerebellar tract were all very large, but there were a number of smaller fibres mixed with them undegenerated, probably belonging to the cross pyramidal system. The degenerated fibres were traced up into the cervical region. In these were some few degenerated fibres on the other side of the cord, probably due to the lesion not being absolutely unilateral.

Two other experiments were made.[2] In one the unilateral section was made at the eighth dorsal. This produced only slight degeneration of the direct cerebellar tract, but there was considerable scattered degeneration in the antero-lateral. In another, unilateral injury of the postero-external column was produced about the level of the first and second lumbar, but the grey matter was not injured; in this case there was no degeneration of the direct cerebellar tract. I did not observe any visceral vascular disturbances in these animals. Of course the great difficulties attending such an experiment as the incision of Clarke's column are almost insuperable on account of the effects produced by injury of other portions of the cord; but the principal portion of the cord injured is the postero-external column, which has to be cut through in order to reach the vesicular column of Clarke. Section of the roots, however, has been shown to cause complete degeneration of the posterior column without any change in the direct cerebellar tract. It may therefore be reasonably concluded that *the cause of the degeneration of the fibres of the direct cerebellar tract is the destruction of the cells of Clarke's column.*

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[1] 'Journal of Physiology,' vol. x., No. 5.

[2] The result of these experiments were made the subject of a communication to the Physiological Society, November, 1889. At the same time the microscopical specimens were exhibited.

Clarke's column extends from the first dorsal to about the second lumbar. It is best developed however in the lower dorsal region. A few somewhat similar cells are found in the sacral region, termed "Stilling's nucleus," and a few in the upper cervical region. Drs. Gaskell and Hill believe that the homologue of Clarke's column in the medulla is the nucleus of the spinal accessory and vagus.

The cells of these "nuclei" are spindle-shaped bi-polar cells—not unlike the cells of Clarke's column, only not so large. And as we know that the lateral horn contains similar cells, which moreover correspond in size, I should be inclined to believe that the larger bi-polar cells seen in vertical and transverse sections of the lateral horn in the dorsal region of the cord corresponded more closely with the cells of the vagus accessory nucleus. The homologue of Clarke's column in the medulla is probably the "cuneate nucleus," the cells of which resemble in shape and size the average-sized cells of Clarke's column. Upon this point Sherrington[1] and I concur.

Dr. Alexander Bruce[2] showed sections of the medulla of the fœtus, which demonstrated that the upward continuation of the "cuneate nucleus" was "Deiter's nucleus," and the cells of this nucleus are in connection with the fibres coming from the semi-circular (deep) root of the auditory, the fibres terminating in this situation. The cells of Deiter's nucleus resemble in size and shape the large cells found in the lower part of Clarke's column, and measure 60μ—90μ in their long axis. Schwalbe states that they are multipolar, and gives the measurement in their long axis as 60μ—100μ. When these cells first begin to appear in the ascending root of the auditory nerve they are mingled with smaller bi-polar cells belonging to the cuneate nucleus. The cells of Deiter's nucleus do not appear to me to be more multipolar in their character than many of the cells in the lower end of Clarke's column (*vide* micro-photo. 2).

If these cells, which closely resemble the large cells of Clarke's column, are connected with the deep fibres of the auditory nerve coming from the semi-circular canal, and serve as a station for the impulses transmitted from the semi-circular canals to the cerebellum, we may consider that impulses connected with equilibration are brought from the skin, joints, and tendons by fibres of the postero-external column to the cells of Clarke's column from the lower extremities, and conveyed thence to the cerebellum by the direct cerebellar tract. Impulses also may be conceived to come from similar situations in the upper portions of the body and to pass to the "cuneate nucleus," of which the cells serve as a station for impulses through the restiform body.

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[1] *Loc. cit.*

[2] Meeting of the Physiological Society at Edinburgh, July, 1890.

Organic sensations from the viscera may also be transmitted, as suggested by Dr. Ferrier, through the cells of Clarke's column to the cerebellum. All the evidence certainly goes to prove that these cells serve as a station for afferent impulses between the peripheral nervous system and the cerebellum. Only one histological fact of a doubtful nature shows that the cells of this column may be connected with the cells of the anterior horn.

There are two other groups of cells found in the spinal cord, which in shape and form differ essentially from the anterior cornual cells. These have been designated by Schwalbe *the intermedio-lateral* and *solitary*. The former are found throughout the dorsal region. The cells are bipolar, and in vertical sections they are often seen to exist as little groups or nests of vesicular cells, from eight to twelve in number. These cells measure on an average 30μ, have their long axis placed vertically, obliquely or horizontally, and closely resemble the smaller cells of Clarke's column. In transverse sections, as also in vertical sections, may be recognised not merely the cells previously described, but also two other sets of cells of a broad spindle shape, placed usually with their long axis horizontal to the transverse section. The small ones, average size 20μ, closely resemble in form and size, and are probably identical with, the so-called solitary cells. This appears to be also the opinion of Sherrington. The larger measure 25μ-30μ, and are probably identical with the cells placed with their axis oblique or vertical. The small spindle-shaped cells attain their full size, or nearly so at birth.

As in Clarke's column, so in this tract we find many cells lying out in the lateral column. The cause of this, together with the mingling of cells of different forms to such an extent, is probably due to the growth inwards of the fibres of the posterior roots, splitting up the cells of the grey matter, which lie posteriorly and laterally to the central canal of the spinal cord during its development n embryo, and also in the early years of post embryonic life, when vertical commissural connections of the cells at different levels have to be established, together with the growth downwards of the pyramidal tracts.

These fibres, both before and after birth, cut off small portions of grey matter, and so the cells become isolated and outlying. I have never seen them lying in the still undeveloped pyramidal tract of the fœtus. I do not make any positive assertion concerning these outlying cells, as I am at present engaged in investigating the matter.

Examination of a series of sections of the spinal cord of a two-years-old child for the determination of the position of the small ovate and spindle-shaped cells situated in the lateral horns :—

1st dorsal.—A few cells.

2nd	,,	Very numerous ovate and spindle-shaped cells ; many placed long axis vertically, 20-30 each side.
3rd	,,	Ditto, 11-15 each side.
4th	,,	,, ,, ,,
5th	,,	Lateral horn well developed ; cells, large and small, 14-16 each side.
6th	,,	Well marked, 15-20 each side.
7th	,,	,, ,, 12-15 ,,
8th	,,	,, ,, 15-20 ,,
9th	,,	Numerous cells ,, ,,
10th	,,	,, ,, 10-15 ,,
11th	,,	Not so numerous.
12th	,,	,, ,,

1st and 2nd lumbar.—Some cells.

At the second sacral, as shown in fig. 4, some small ovate bi-polar cells were discovered in the sections. Too much reliance, however, cannot be placed upon this fact, because a large number of sections were examined in order to see if cells existed in this region which could, from their size and simple form, be associated with the small fibres which Gaskell has shown to emerge from the spinal cord in this region. The medium-sized bi-polar cells found in the intermedio-lateral tract correspond in form and size with the cells of the vagus nucleus, and it may be considered that the smaller cells give origin to the fine fibres which pass out of the anterior roots throughout the dorsal region. This certainly seems much more probable than that they should come from the cells of Clarke's column. Throughout the dorsal region at the base of the anterior horn are found numerous small angular and spindle cells. These are found also in the upper cervical region, and probably are connected with fine efferent fibres.

Fine root fibres enter the posterior cornu on the outside, although they cannot be traced directly into the small bi-polar cells found at the base of the posterior cornu, and in the intermedio-lateral tract it is quite possible and probable that these small fibres find their station in these small cells, which are placed, with their long axis, horizontally, so that we might consider one pole of the cell to be connected (though not directly) with an organic sensory fibre, the other pole being continued forwards and outwards as a fine efferent fibre. Fine fibres certainly can be seen in vertical sections passing out through the lateral column, as represented in the diagram. Owing, however, to the cells being usually cut across it is difficult to trace the fibres any distance, because they tend to run forwards and outwards (*vide* fig. 3). In vertical sections of the lower dorsal regions large coarse fibres can be seen running across the lateral column. These are probably going to the direct cerebellar tract.

With regard to the larger cells resembling those of Clarke's column found in the intermedio lateral tract, with their long axis placed vertically, it is possible that these may be connected with fibres of the ascending antero-lateral. I think that the inter-medio lateral probably contains cells belonging to different systems, those placed vertically being connected with an ascending set of fibres, antero-lateral, those placed horizontally with efferent root fibres.[1]

Moreover the development of the spinal cord supports the view that the intermedio-lateral tract gives origin to the splanchnic efferent fibres of the anterior roots. ~~He~~ has shown/ His that there are two kinds of efferent fibres, somatic or ventral, and lateral or splanchnic, and these take origin from entirely different parts of the basal lamina of the neural tube. The former originating from groups of neuroblasts, near the middle line, the latter near the junction of the basal with the alar lamina. In connection with the origin of the cranial efferent nerves, Schäfer states that :—

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[1] Bechterew, '*Uber den Nerven Wurzeln*,' *Archiv. für Anatomie*, 1887.

"They are disposed in two longitudinal series, one of them comprising the nuclei of origin of the somatic efferent nerves of Gaskell, which correspond with the largest fibres of a typical anterior spinal root, and the series of nuclei is a continuation of the cell column of the anterior horn. The nuclei of this series are the 12th, the 6th, 4th, and 3rd. The other series comprises the nuclei of origin of the splanchnics, efferent nerves of Gaskell, which correspond with the medium sized and smaller fibres of a typical anterior spinal root, *and the series is a continuation mainly of the cells of the lateral cornu of the intermedio lateral tract*, and partly perhaps of the cells of the base of the posterior horn. The nuclei of this series are those of the spinal accessory, those of the efferent fibres of the vagus, glossopharyngeal, facial and motor nucleus of the 5th."—QUAIN, vol. i, part 1.

Lying in the grey matter of the base of the posterior cornua, especially on the outer side, are numbers of bi-polar cells of a spindle shape placed with long axis horizontal, and with processes directed forwards and backwards—the so-called *solitary cells.*

In conclusion, although many writers have stated that Dr. Gaskell has *proved* that small efferent fibres of the anterior roots of the dorsal region are connected with the cells of Clarke's column, it is as well to state that this eminent authority did not exclude the possibility that they originated from cells of the inter-medio lateral or the solitary, which I have endeavoured to show is much more probable. Dr. Gaskell was under the impression that the cells of Clarke's column are small—hence the inference that small fibres are probably connected with small cells; and inasmuch as the distribution of Clarke's column corresponds to the outflow of fine fibres, it was natural that he should have leant to the view that Clarke's column was their source rather than the other groups mentioned by him. Gaskell[1] has recently referred to the cells of Clarke's column as divisible into two groups of different sized cells. Sherrington, in a footnote concerning this point, makes the following statement :—"I must confess, however, I have not been able to convince myself of the division of the cells into two groups, nor do I interpret the observations of Mott[1] to be in support of the division of cells into two groups." I think I can explain this discrepancy.

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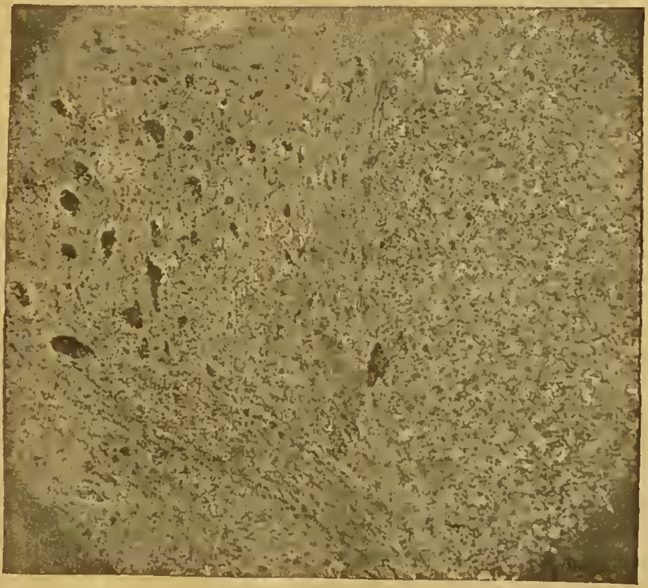
[1] 'Journal of Physiology,' vol. x., p. 157, 1889.

Schwalbe[1] has pointed out in connection with the anterior cornual cells, that where a column is well developed the cells are larger—therefore the cells of the lower end of Clarke's column are larger. Moreover, owing to their connections with the fibres of the postero-external column on the one hand, as shown in fig. 2, and on the other hand with the fibres of the direct cerebellar tract, the cells are placed not with their long axis vertical, but either obliquely or horizontally, so that they appear in transverse sections much larger here than higher up. Consequently in transverse sections of the lower end of the column one sees the long axis of the cell, whereas higher up one sees the vertically-placed bi-polar cell cut transversely, and, therefore, only the narrower transverse axis is measured. I also stated that in the postero-external column were two sets of fibres, large and comparatively small, as shown in micro-photo. 2. The former I believed to be connected with the larger cells of Clarke's column, the latter with the smaller. This may be so, but still the impulses passing through the cells would be afferent. From experimental observations I am more inclined to believe that these smaller fibres belong to Goll's column, being on their way there through the postero-external column. This much may certainly be said, that the smallest cells I have seen in Clarke's column, under any circumstances, have been larger than the largest cells found in the other two groups. This fact, when coupled with the fact that at birth the cells of Clarke's column are only one-third of the size of the cells at two years, strongly suggests that they are not connected with fine efferent fibres having an organic function such as the innervation of the visceral-vascular system.

Moreover, the whole of the cells of the spinal cord would be absorbed for efferent fibres, according to Dr. Gaskell's theory, leaving no cells for two distinct afferent tracts to the brain, viz.,the direct cerebellar and antero-lateral, which have been shown not to have their origin in the ganglion cells of the posterior root.

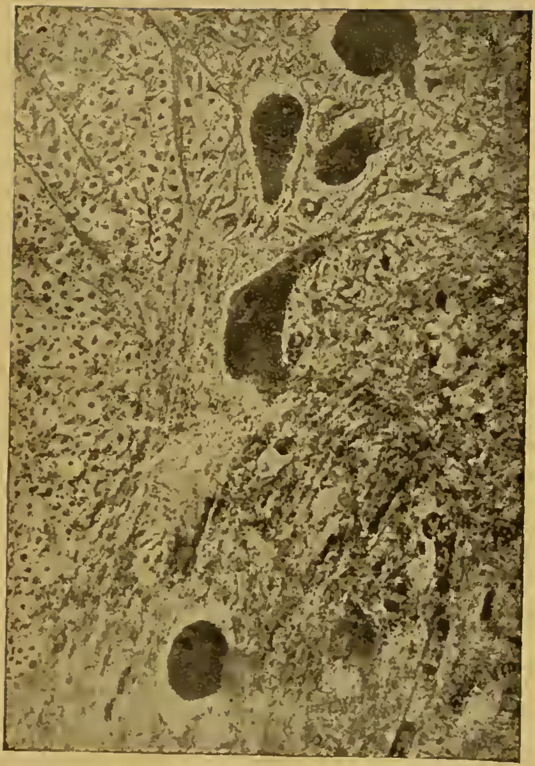
[1] *Loc. cit.*

TO ILLUSTRATE DR. MOTT'S PAPER ON THE BI-POLAR CELLS OF THE SPINAL CORD AND THEIR CONNECTIONS.



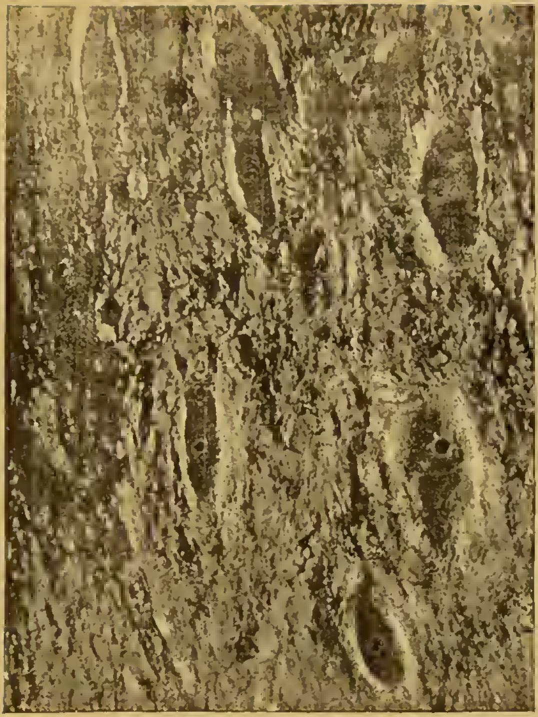
MICRO-PHOTO. I.

Transverse section of fœtal spinal cord, lower dorsal region, shewing cells of Clarke's column; magnified 150 diameters.



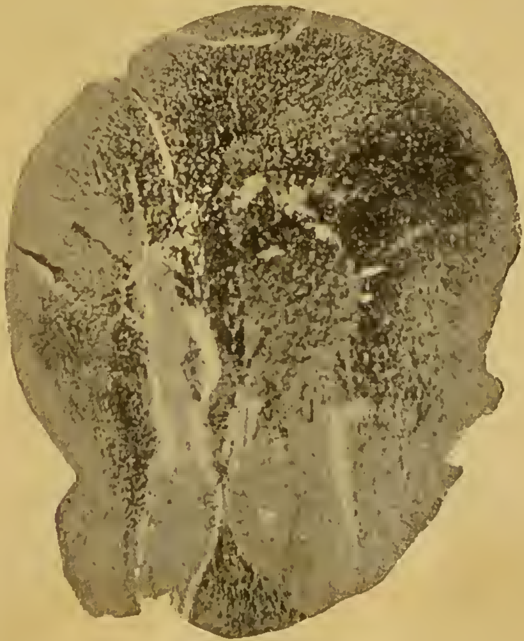
MICRO-PHOTO. II.

Transverse section of Clarke's column in the lower dorsal region (11th-12th segment), showing many large cells; and, in the fibrillary net work, large fibres are seen cut transversely. Magnified 250 diameters.



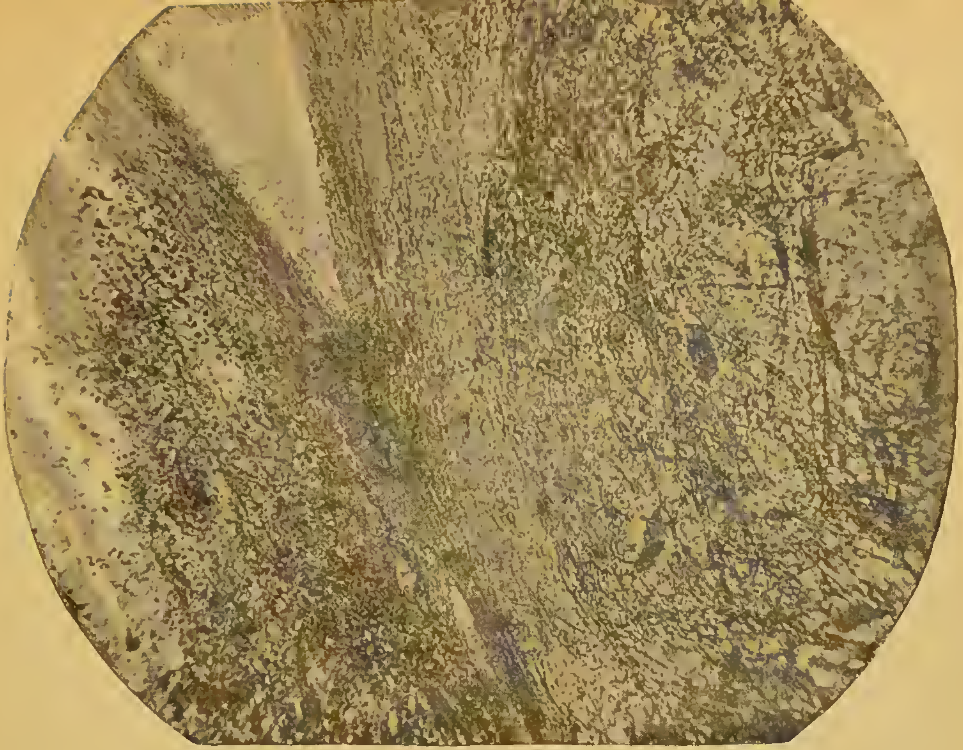
MICRO-PHOTO. III.

Vertical section of Clarke's column shewing the large bi-polar cells lying in a spongy network of nerve fibrillæ. In the original photograph the fine fibrils can be seen passing across the lymph space to join the cell. Magnified 250 diameters.



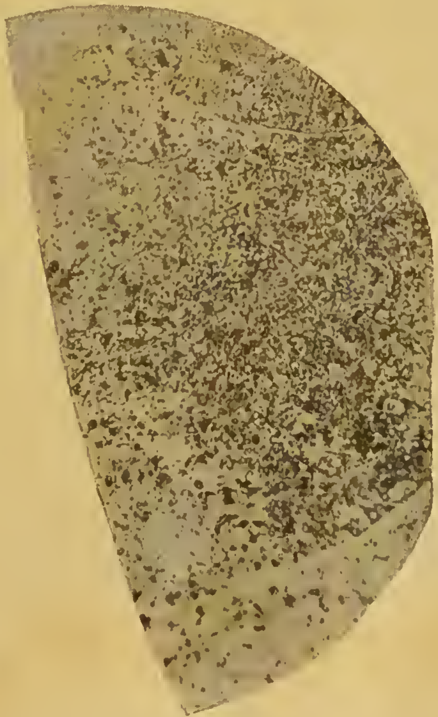
MICRO-PHOTO. IV.

Spinal cord of monkey at 12th dorsal. The seat of the lesion is seen on the left side. Destruction of nearly the whole of the grey matter on that side, and shrinking of left half of the spinal cord. Magnified 10 diameters.



MICRO-PHOTO. V.

Clarke's column from the previous section. as seen under a magnification of 150 diameters. On the right hand side of the central canal are seen the cells lying in a fibrillary network; on the left, disappearance of the cells and atrophy of the network.



MICRO-PHOTO. VI.

Portion of the lateral column in the mid-dorsal region on the side of the injury, showing the degenerated fibres, stained by Weigert's method, after hardening in celloidin. Nearly all the degenerated fibres are seen at the periphery in the direct cerebellar tract. Magnified 100 diameters.

The average size of the cells of Clarke's column at birth is 25μ—30μ, and therefore one half the size of the cells at two years.

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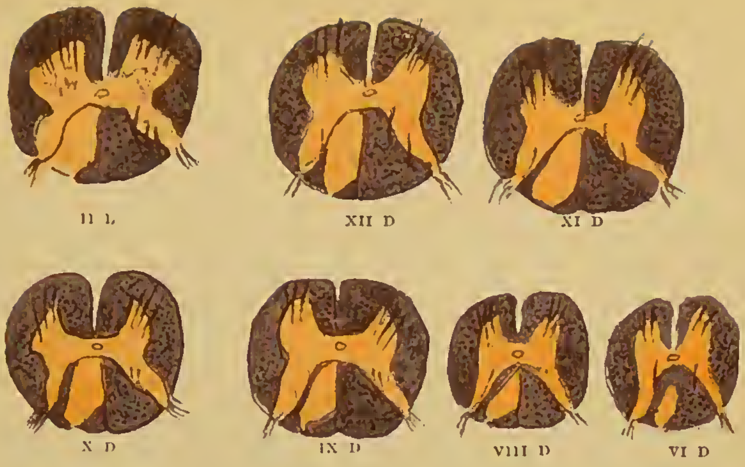
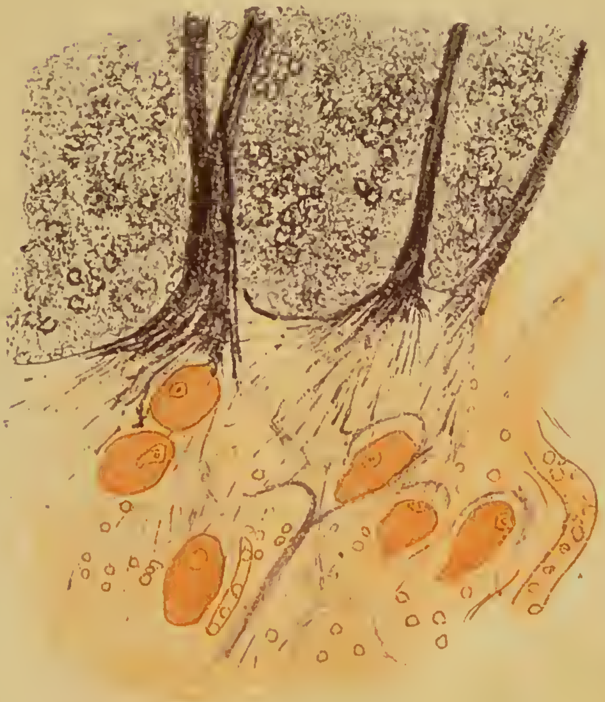


II L XII D XI D

X D IX D VIII D VI D

I.—Unilateral section of the roots of the Cauda Equina in the Monkey.

Mag. 4 diameters.



II.—Clarke's Column human spinal cord, 12th dorsal. Fibres from postero-external column entering and terminating in a brush of fine varicose fibrils around the cells which are for the most part cut across obliquely.—Mag. 250.

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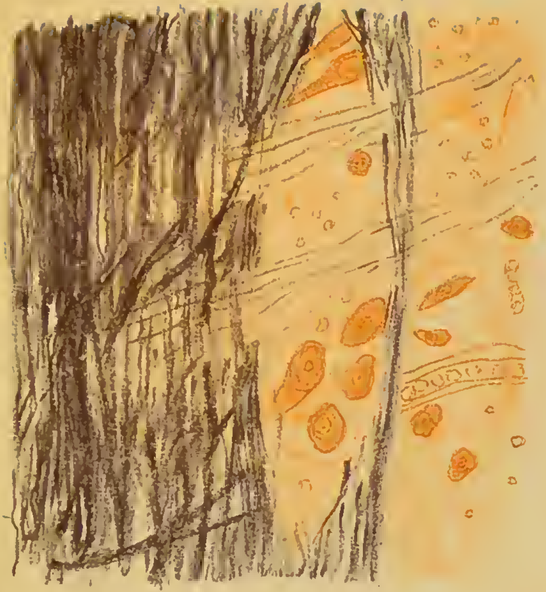
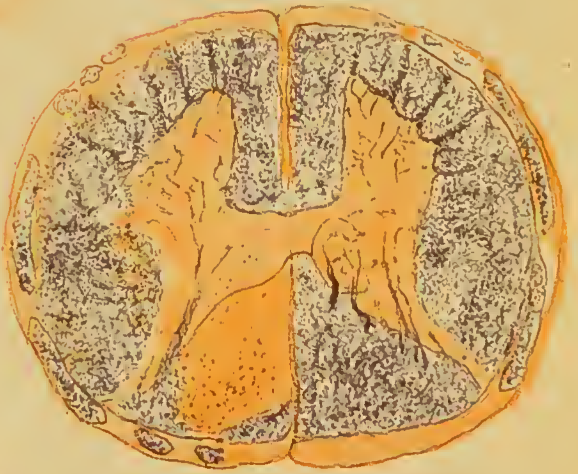
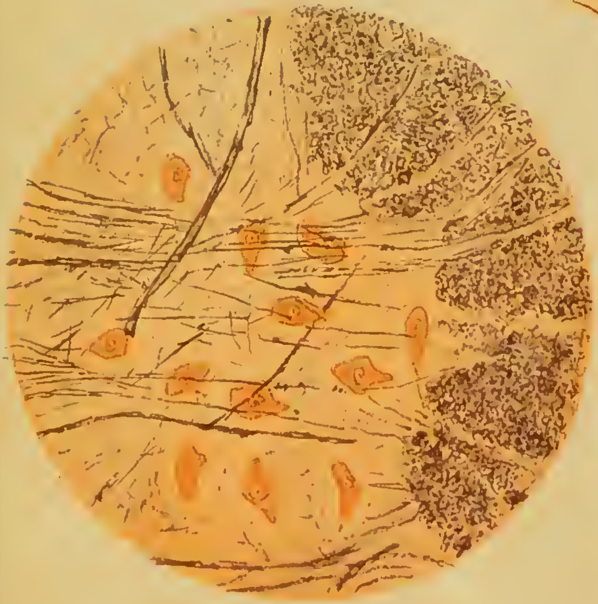


III.—Vertical section of lateral column and intermedio-lateral tract mid dorsal region, 2 yr. human spinal cord.
Mag. 250 diameters.

V.—Spinal cord of Monkey at level of 12th dorsal. Degeneration of postero-external column on left side as a result of section of 3d, 4th, and 5th lumbar and 1st and 2d sacral. Atrophy of nerve plexus around cells of Clarke's column on the same side.
Mag. 10 diameters.





IV.—Cells of intermedio-lateral seen in transverse section of 2d sacral.
Mag. 250 diameters.

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